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THE MULTIPLE POSITION LETTER SORTING MACHINE. AN EVALUATION OF --ETC(U)
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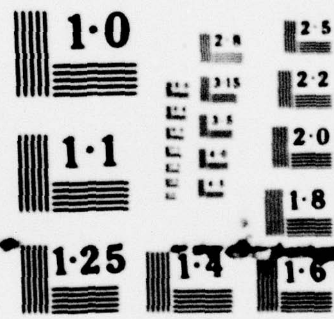
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An Evaluation of Visual, Auditory, and Human Factor Problems.

Report of a Joint Working Group

Committee on Vision

Committee on Hearing, Bioacoustics, and Biomechanics

Assembly of Behavioral and Social Sciences

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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JOINT WORKING GROUP ON PROBLEMS RELATING TO THE MULTIPLE POSITION LETTER SORTING MACHINE

Committee on Vision
Committee on Hearing, Bioacoustics, and Biomechanics

Members

J. W. GEBHARD (Chairman), Applied Physics Laboratory, Johns Hopkins University (retired)

NANCY ANDERSON, Department of Psychology, University of Maryland

ERICH K. BENDER, Bolt Beranek and Newman, Inc.

ROBYN M. COX, Memphis Speech and Hearing Center, Memphis State University

DONALD E. ERWIN, Human Factors Group, Bell Laboratories

DAVID ROBINSON, Department of Ophthalmology, Johns Hopkins Medical School

ROBERT SEIBEL, Department of Psychology, Pennsylvania State University

JOHN C. WEBSTER, National Technical Institute for the Deaf, Rochester Institute of Technology

Staff

KEY DISMUKES, Study Director, Committee on Vision (present)

LUIS PROENZA, Study Director, Committee on Vision (8/77-5/79)

MILTON A. WHITCOMB, Study Director, Committee on Hearing, Bioacoustics, and Biomechanics

MICHELLE F. EABON, Administrative Secretary, Committee on Vision

ARLYSS K. WIGGINS, Administrative Secretary, Committee on Hearing, Bioacoustics and Biomechanics

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PREFACE

At the request of the U.S. Postal Service, the Committee on Vision and the Committee on Hearing, Bioacoustics, and Biomechanics established a working group to help evaluate visual, auditory, and human factor aspects of the Multiple Position Letter Sorting Machine. Letters are sorted at this machine by human operators who read address codes on letters displayed before them and then direct the letters to appropriate bins by operating a keyboard. Studies of operator performance on this machine have yielded differing estimates of operator error rates; in some cases a high error rate was reported. The working group was asked for advice on reducing operator error rates and to review and comment on studies proposed by a U.S. Postal Service task force concerned with improving operator productivity.

The working group received a detailed briefing on the Multiple Position Letter Sorting Machine and its use from Rebecca Gray of the U.S. Postal Service and met with members of the task force to discuss operational and personnel problems. Two installations were visited--an old one at the Washington, D.C., post office and a new one at the Merrifield post office in Virginia. The working group observed performance of all operator functions of the machine in these offices, questioned supervisory personnel, and examined and operated the keyboard training console. In addition, much of the extensive literature on operator problems associated with mail-sorting machines was obtained and studied.

This report contains the working group's evaluation of each of the six actions proposed by the U.S. Postal Service task force. The working group found that operator problems have already been characterized by existing literature, and in our investigation we found no evidence of major problems of an auditory or visual nature that had not been previously identified. In the course of the study, however, it became apparent that human factors such as motivation and the nature of the operator-machine interaction have a major impact on operator error rates. Consequently, this report includes discussion of these human factors and recommendations for related actions. Changes in operator procedures or in the design of the operator-machine interaction might involve substantial personnel policy issues or cost considerations, which are beyond the purview of this report: thus, the conclusions of

this report are presented in terms of potential actions recommended for feasibility study by the U.S. Postal Service.

The working group acknowledges the valuable assistance of Alan H. Harris of the Johns Hopkins University School of Medicine in assessing the nature of stress involvement in the letter-sorting task.

J. W. Gebhard, Chairman
Joint Working Group

THE MULTIPLE POSITION LETTER SORTING MACHINE:

An Evaluation of Visual, Auditory, and Human Factor Problems

SUMMARY

The joint working group was asked by the U.S. Postal Service (USPS) to examine visual, auditory, and human factors in the operator use of the Multiple Position Letter Sorting Machine (MPLSM). Specifically, the group was asked to review and comment on avenues of study proposed by the USPS to reduce operator error rates, which are reported to be unacceptably high at some installations.

The group concluded that changes in certain aspects of the operator-machine interaction and in personnel procedures have potential for considerable improvement in operator performance. Thus the group recommends that the USPS study the feasibility and potential cost-effectiveness of:

1. Changing the MPLSM from machine pacing to operator pacing.

2. Providing an error key to enable operators to correct reading or keying mistakes they detect themselves.

3. Providing on-line performance feedback to operators.

4. Setting up a motivational system to reward the achievement of low error rates by operators.

Since these changes may involve considerable expense and revision of personnel policies, the USPS would need to perform a comprehensive cost-benefit analysis to determine whether they would be desirable. To evaluate the effectiveness of any change in MPLSM procedures adequately, it will be necessary to institute a program to measure baseline error rate.

The group considered the possibility of changes in operator seating, keyboard and coding arrangement, operator work cycles, illumination and noise, and environmental heating, cooling, and ventilation. The group concluded that such changes would produce at best only comparatively small improvement in operator performance. Nevertheless, because of the enormous volume of mail that is currently handled, even small improvements in error rates might produce appreciable savings.

Finally, the group concluded that automatic sorting of mail by machine-readable codes has more potential for producing low error rates than does any change that might be made in operator procedures. However, adoption of an automated system could involve major personnel, social, and political considerations that go beyond the scope of this report.

INTRODUCTION

Background

In order to improve productivity on the Multiple Position Letter Sorting Machine (MPLSM), the United States Postal Service (USPS) in 1977 established an MPLSM job design program. The plan of the program states:

> By a detailed study of the task requirements, an analysis of the work station design, an assessment of the work environment, and a review of potential occupational disease inducing job factors, it is projected that a decrease in operator errors, a reduction in job turn-over, and an increase in job satisfaction can be obtained.

To accomplish the program's objectives the USPS set up a task force, consisting of representatives from various branches related to its service operations, employee and labor relations, and research and development. This task force identified areas in which study was needed and outlined potential sources of improvement in MPLSM productivity. Six actions were proposed:

1. To collect baseline operator performance data on the MPLSM; in particular, to measure operator error rates.

2. To assess and specify the visual requirements of the operator's tasks.

3. To collect measurements of the noise levels associated with the MPLSM and its environment.

4. To collect measurements of potential physiological indicators of stress and fatigue.

5. To assess the potential for MPLSM tasks to produce occupational disease.

6. To conduct a task analysis of the operator's visual and manual functions on the MPLSM, with particular attention to the operations at the keyboard.

This report includes an evaluation of each of the task force's six proposed actions.

The Machine

The MPLSM is an electro-mechanical machine about 80 feet (24.4 meters) in length, weighing 14 tons (12,700 kg). There are 12 operator consoles on the input side of the machine where the mail is received for sorting, and 277 bins for sorted mail on the output side. Letter-size mail arrives in trays and is stacked manually on edge in proper orientation on the feeder tray assembly of each operator console. Stacked letters are then mechanically picked off the front of the stacked mail by a vacuum head, transported to a window, and dropped on the bottom edge with the address facing the operator. At each of the 12 consoles, trained operators read address codes at the rate of 60 letters per minute and sequentially depress keys that send each letter to the designated destination bin on the exit side of the machine. MPLSM operators spend 30 minutes at the keyboard console and then take turns at the tasks of stacking the mail at the input trays and removing the mail from the destination bins.

The Operator's Task

The operator's task at the console is a difficult one, and it includes some unnatural responses that require much practice to learn proficiently. The MPLSM is set to automatically present one letter per second to an operator who must first read the ZIP code while the letter is stationary in the viewing area; then, after the letter begins to move out of the viewing area, the operator must key in the code. If the letter does not contain a ZIP code (which reportedly is the case for about 30 percent of the mail), the operator must recall from memory the keypunch code for that particular address. During the stationary period the keyboard is inactive and the machine will not accept an input. Operators, therefore, may key too early or too late in addition to keying inaccurately. No mechanism is provided to correct mistakes detected by the operator.

Workers on the output side of the machine are responsible for checking the contents of the destination bins for letters keyed in error. This task is supposed to be done simply by riffling a handful of mail and attempting to spot missorts as they fan by.

FINDINGS AND CONCLUSIONS

Operator problems encountered with the machine sorting of mail have been clearly recognized in previous studies (see, for example, Cornog 1974, 1976; Devoe and Kinsley 1969). The working group found that MPLSM operator problems are well characterized in the literature and, furthermore, it found no evidence of any other major problems previously unrecognized.

Baseline Error Data Collection

A major recurrent problem in evaluating operator performance on the MPLSM is that of determining what that performance actually is. The USPS claims that a 12- to 17-percent rate in distribution errors exists in some offices, and other sources indicate a range of error estimates. A 2-percent error rate was reported by the Western Region USPS (1975), yet a report of the Comptroller General (U.S. General Accounting Office 1974) found that 30 percent of operators audited had error rates of more than 10 percent, and only 18 percent had error rates within the 2-percent rate then allowed. As a general procedure for determining errors nationwide, the infrequent audits conducted on the operators by supervisors are not adequate for assessing the effect of any equipment or procedural changes that might be recommended. Even frequent audits would not eliminate this problem (Devoe and Kinsley 1969; Cornog 1976); Cornog (1976) notes that audits:

1. Constitute an unknown mixture of man and machine errors.
2. Sample only a portion of the operator errors.
3. Are difficult to track back to the individual operator.
4. Are not scored consistently from post office to post office.

An adequate method of measuring errors is required not only to provide baseline performance data, but also to provide a possible means for supplying frequent feedback to the operators to improve motivation. Such feedback is not adequately provided by workers checking the output bins for missorts. In fact, clandestine observation of bin sweepers revealed that frequently they did not riffle the output for errors at all. The requirement for incentive programs has recently been recognized by regional offices (U.S. Postal Service 1974, 1978). Appendix A treats in detail the methods of measuring errors used by these regions.

The working group also considered methods of collecting baseline error data that would assess the overall sorting performance of the MPLSM. In the first method, the same sample of mail supplied to an MPLSM is processed twice: first by unselected operators assumed to

be representative of the population; second by selected operators known to be capable of achieving the 2-percent error criterion. The sorts by these two groups are then compared. In the second method, mail that is pre-analyzed so that the sorts will be known is processed by the unselected operators. Operator performance is then compared with the known sorting. In neither of these two procedures can the errors be traced to specific operators, nor can machine errors be identified.

A third method involves printing a code (machine number, console number, and sequence of keys) on each envelope each time an operator uses the keys so that each operator's sorts can be later identified. Another method that would identify the operators who make errors is to make more extensive and systematic use of an augmented version of the present auditing computer than is now done. However, these procedures, too, will not identify those errors contributed exclusively by the machine. In order to determine the percentage of letters correctly keyed by the console operator but directed to the wrong bins by the transmission mechanism of the machine, a check for the contents of the bins must be made. (This requirement also applies to the approach described below.)

A more ambitious approach, which the USPS might consider, would be to develop and apply a system that would record keying errors at the console and, at the same time, collect collateral data applicable to other aspects of the USPS program plan. One such method could be a mobile system that would record simultaneously with time:

> A video tape view of the operator's keyboard and hands, to determine finger motions, sequences, delays, and keys struck. The tape would include a view of the letter in the window, which would show the ZIP code, its position, and its legibility.
>
> A video tape view of the operator's eyes, to show eye movements in scanning, blink rate, and pupillary changes.
>
> Electronic encoding of keystroke operations on the video tape, to record effective keystrokes and timing information in relation to machine functions.

From these records it would be possible to collect data on keying errors, operator keying behavior, visual scan patterns, and visual responses, which may change with time on the console. It would also be possible to determine from these records what operator behaviors are associated with low error rates. This information would be useful in the design or refinement of training programs. Since these data would be time correlated, their interdependence can be determined. Such a recording system would be sophisticated but feasible; more significantly, the analysis of the recordings would be time-consuming. Specifically, it would be necessary to score the recorded data manually.

It would be desirable to apply this recording system on a non-interfering basis to MPLSMs located in post offices in the field. This may be impossible; if so, it would still be valuable to install such a system at an MPLSM simulator facility.

Any procedure for measuring baseline error rate will be difficult and costly. However, without such a system the USPS will have no basis for evaluating changes in performance produced by modification of any aspect of the MPLSM task.

Visual Considerations

The working group found that screening of new operators with the Titmus Vision Tester, as is currently done, is adequate for the visual requirements of the operator's task. The group recommends that new operators be required to pass a near acuity test with corrected vision, and that testing proceed in the conventional order of right eye, left eye, both eyes. The current testing for heterophoria (squint, improper functioning of the muscles controlling the eyes), is unnecessary, but visual field screening is appropriate. Properly fitted eyeglasses, with or without bifocal lenses, appear to present no problems, as the operator fixes the center of the viewing window where the letter is stationary and does not need to search widely in any direction.

Although the operator's task is not sufficiently demanding to require a comprehensive ophthalmological examination, such an examination might be useful to the USPS as a baseline against which to evaluate any future allegation of eye damage from the onerous keying task, or if illness records show appreciable numbers of eye complaints. However, the group sees no likelihood of job-related ophthalmic disease resulting from MPLSM operation (see the section on occupational hazard and disease, below).

At the two installations visited, the illumination level at all stations of the MPLSM was observed to be adequate for the activities being carried out. Measurements of illumination made at the plane of the letter for a number of machine consoles showed values in the range of 20 to 140 footcandles (1 footcandle = 3.382 lumen/m^2) with the auxiliary light rheostat set, respectively, at minimum and maximum. Since reading the letters at the console is the most critical visual task, a level of 100 $\pm$ 20 effective footcandles is recommended for this work station (Smith and Rea 1976; U.S. Federal Energy Administration 1975) and can be achieved with the present equipment. Significant gains in operator performance would not be expected from a further increase in the level of illumination.[1]

[1]A comprehensive assessment of the general relationship between performance, illumination level, and energy costs is being carried out by another working group of the Committee on Vision; it is expected to be completed in 1980.

Measurements taken in the hallways on either side of the machine showed illumination levels generally falling within the range of 50 to 60 footcandles, which are appropriate to the tasks performed at those stations.

While some glare could be found at the console side of the machine, the effect was not considered severe enough to be important. Indeed, glare control has been accomplished rather well, and the treatment of the local field surrounding the letter to be read presented no unsatisfactory difference in contrast.

The working group considered visual aids for the operators, or fitting the machine with a magnifier, but concluded that the operators adequately read letters under present conditions and that special aids would do nothing to enable the reader to decipher poorly written addresses.

Auditory Considerations

Ambient noise level measurements taken at the Washington, D.C., and Memphis, Tennessee, post offices showed values in the range of 80 to 84 dBA in the areas occupied by workers on the MPLSM. Present federal regulations on occupational noise exposure permit daily exposure to no more than 90 dBA for an 8-hour day, and the levels measured are well within that limit. If noise levels at installations not visited by the working group are to be checked, measurements should be obtained using a sound level meter (Type I or Type II re: ANSI SI.4-1971) with the microphone located a few inches from the operator's ear.

The dBA noise level measured at the Washington installation is typical of the level experienced inside the passenger cabins of jet aircraft. For sustained speech communication of a critical nature, 70 dBA would be a limiting ambient noise level (Webster and Lepor 1969). Letter sorting machine operators do not require highly intelligible speech communication as an essential part of their job. Nevertheless, when necessary, personal communication in 80 dBA noise can still be carried out with the vocal effort normally expected in the presence of noise when the speakers are about two feet apart (Webster 1970, 1973, 1979). Thus, the noise levels associated with the MPLSM do not eliminate occasional personal conversations, and, by keeping these conversations to a minimum, may in fact tend to allow better concentration on the job.

Some MPLSM operators wear earphones while working at the keyboard. Music fed into these phones is controlled by supervisory personnel. The earphones, normally supplied with muffs, will produce about 15 to 20 dBA attentuation of the 80 dBA noise. If the supervisor sets a music level of no more than 70 dBA, the music can still be comfortably heard and the overall sound level at the ears will be within safe limits. As for

the effect of music on performance, no data can reliably predict attitude (or performance). Some people like it, some don't--it appears to be a matter of employee choice, as was observed at the MPLSM consoles. For operators who simply wish to reduce noise level (without music), effective earplugs could be provided.

Laboratory studies on the effect of ambient noise on task performance have produced ambiguous results (Broadbent 1957; Cohen 1969; Kryter 1960). Most studies have used well-motivated college students and noise levels higher than 80 dBA. Generalization to the MPLSM situation would be difficult even if the results were definitive. Some studies have noted that workers reported feelings of irritability, annoyance, and unpleasantness with noise levels that produced no measurable decrement in performance, and this factor might conceivably contribute to absenteeism from the MPLSM job.

The working group concluded that a noise level of 80 dBA is not a limiting factor for job performance on the MPLSM and that a large effort to reduce noise below 80 dBA would have little effect on operator error rates.

Stress and Fatigue

Stress and fatigue are poorly defined conditions operationally, although they are thought by most people to be well defined subjectively. Of the two conditions, fatigue is the better understood and more amenable to measurement in terms of performance decrement with time, often accompanied by certain changes in body chemistry. With respect to stress (Mason 1975a, 1975b; Selye 1975), physiological measures such as heart rate, respiration, blood or urine analysis for adrenal hormones, lactic acid, and catecholamines will probably not reveal clinically significant changes over the short term. This question, however, is an empirical one. The National Institute of Occupational Safety and Health is presently conducting studies relevant to this issue (see Smith et al. 1978).

A simple, unobtrusive effort would be to carry out an examination of absenteeism, turnover rates, sick call, and medical records for complaints of fatigue and stress in MPLSM operators as compared with other job classifications or in MPLSM operators with 1, 5, and 10 years of experience compared with one another. Such data, if available, might provide a measure of stress and fatigue that would be both easier to obtain and more relevant to the USPS situation. Another possibility is the administration of a self-report stress and fatigue inventory specially tailored to the MPLSM task. If the composite recording system suggested above (in the section on baseline error data collection) were instituted, it might then be useful to analyze reaction time and eye response (blink rate and pupil diameter) data that would be available, as possible indicators of stress and fatigue.

Occupational Hazard and Disease

As discussed above, the working group found no evidence of visual or auditory hazard from the MPLSM operator's task. To determine whether there are any cumulative health effects of stress involved in MPLSM operation would require long-term prospective or epidemiological studies that are beyond the scope of this working group.

The Keyboard Operator's Task

The working group considers the operator's task at the keyboard console to be a difficult one, and some aspects of the keying response require considerable practice to learn proficiently. Nevertheless, operators do learn this demanding, high-speed, machine-paced task and appear, on casual observation, to be keeping up with the job. They do not seem to be laboring; they have time to manipulate the keys and even to glance away from the viewing area occasionally. There remains, however, the high error rate reported by the USPS, and until the error rate is measured more definitively by some system (such as those described in this report), there is no way to isolate the contributing factors.

In its analysis of operator keying activities the working group considered several procedural changes that might affect operator efficiency. Major attention was given to the possibility of alterations in keyboard design, pacing, detection of errors, error rate feedback, and operator motivation.

Keyboard Design

The working group concluded that a superior keyboard and coding layout could be developed based on available evidence (Seibel 1972) or in a suitable research and development effort, but that a better keyboard or code by itself would contribute little to reducing error rates. A new keyboard or code might simplify and shorten the training period, but its overall effect in the face of the motivational problems that beset MPLSM operations would be minor. That is, although the MPLSM operator might be able to go through training more quickly, accuracy of performance by an experienced operator on the job would not be expected to be much improved because of a more "natural," easier-to-learn keyboard and code.

Form of Pacing

A number of factors suggest that converting MPLSM operation from machine pacing to operator pacing might have a major effect on operator error rate. First, machine-paced keying speeds may be too high for some

operators or too low for others, or too high for many operators on "off" days, or too high for all operators when fatigue sets in. Also, operator pacing would let the operator key while the letter was stationary, allowing time to read and decipher troublesome addresses.

Several studies suggest advantages of self-paced tasks as opposed to machine-paced tasks. Simple serial reaction times are more accurate and faster under self-paced conditions (Beck 1963). Four-choice reaction time responses are more accurate and reaction times less variable under self-paced conditions (Wagenaar and Stakenburg 1975). A simulated inspection task experiment suggests (McFarling and Heimstra 1975):

> The self-paced inspection situation appears to possess advantages with respect to both performance and motivational aspects...a self-paced situation may be structured to encourage accuracy rather than speed and still realize a reasonable level of total task accomplishment. In contrast, a machine-paced situation may tend to emphasize speed in decision making even when sufficient time does exist to conduct accurate inspection.

Actual letter sorting in a British post office was studied by Conrad (1960a, 1960b, 1960c). The machines were self-paced with an enforced lag of 0.55 second following each sort. At the end of a year, average production sorting rates approached 60 sorts per minute for the seven postal employees studied. There were some important differences between their task and that of MPLSM operators, so direct comparisons are not warranted. However, the data that are relevant are the distributions of the times (latencies) between the successive code entries. No times were less than 0.55 second because of the lag built into the machine. By the end of the study approximately 75 to 85 percent of the latencies were 1 second or less, with most (35 to 60 percent) within the 0.6- to 0.8-second range.[2] While the percentage may vary somewhat from one operator to the next, the important generalization is that the skilled operator has adapted to the enforced lag and is sorting at near maximum rate for most letters. Despite this rapid performance, it is most important to note that approximately 20 percent of the latencies were greater than 1 second. If the task had been machine-paced at a 1-second rate, the distribution would probably have fewer latencies of more than 1 second, but there would undoubtedly still be some--leading to re-sorts or errors for those letters and the ones that followed them. Conrad does not report error rates for the self-paced sorting, but the data strongly suggest that an important source of error in the MPLSM operator's task is the 1-second machine pacing.

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[2] The percentages are estimated for a "typical" distribution from Figure 2 (Conrad 1960b) and Figure 3 (Conrad 1960c).

These findings strongly suggest that it would be useful for the USPS to institute a study of MPLSM operator performance in which operator pacing is compared with machine pacing. This would require an adequate performance and error recording system, and the overall cost-effectiveness of the two systems would need to be analyzed. Since high levels of skill develop slowly it would be crucial for each operator in such a study to work exclusively under his or her assigned pacing condition for as long as a year, with relative performance evaluated during the last several months.

Error Detection Key

Skilled keyboard operators themselves detect many, if not most, of the keying errors that they make, 70 percent according to Klemmer (1971). West (1969) reports this to be true for typists, and Conrad (1960c) reports it for a simulated letter-sorting task. Klemmer and Lockhead (1962) estimate self-detected key punching errors to be four times as frequent as non-detected errors (later detected via verification). The West study also strongly suggests that kinesthetic (muscular and joint) sensations help the skilled typist to detect about 40 to 50 percent of the total number of errors made. Inclusion of opportunity for the skilled typist to visually check on "suspected self-detected errors" increases the self-detection rate to between 60 and 75 percent. Visual feedback in a self-paced task may make a significant contribution in reducing undetected errors. This could be accomplished in the MPLSM situation by providing an electronic display of the code just keyed, with the display being positioned close to the envelope that generated that coding response. In conjunction with the display, operators could be given the capability to correct self-detected errors with a character or "word" erase key or be provided with a separate key that would at least send the incorrectly keyed letter to a re-sort bin rather than to an incorrect bin.

Error Rate Feedback

The present system of occasionally auditing individual operator performance does not provide the operator with adequate feedback about individual error rate. A score, for example, given after each 30-minute period on the machine would do much to increase individual motivation. The working group appreciates the difficulty inherent in providing error feedback on a near continuous basis and sees no solution to this problem, except by adding an operator to the MPLSM crew to provide the necessary audits. The cost-effectiveness of such an error auditor would have to be investigated.

Motivation

Problems associated with operator selection, training, and motivation have long been recognized (Cornog 1974; Devoe and Kinsley 1969). As it now stands, the operator at the console is physically and psychologically isolated, with little incentive to contribute positively to an outcome of which he or she has little knowledge. It was established by the USPS that some operators can key with 98-percent accuracy in selected trials, yet the operator-wide average is claimed to be far less than this. In spite of high pay (over twice that received by personnel operating bank proof machines), turnover and absenteeism are high, and there is much complaint about the job.

The working group considered several reasons for the number of complaints. First, the 98-percent criterion accuracy rate is probably perceived as unattainable by the majority of MPLSM operators as well as their supervisors, who were formerly console operators. Operators feel that no matter how hard they try, criterion performance is not possible. Second, operators do not associate desirable outcomes of their job, such as advancement or recognition, with the attainment and maintenance of low error rates. In fact, if a dissatisfied MPLSM operator returns to a less exacting job, he or she receives only a small reduction in salary. Third, there is no collective commitment to the attainment of high accuracy by MPLSM crews. Since frequent feedback of measured error rates is not provided, no means is available to establish crew competition.

It is the consensus of the working group that attention to procedures to increase operator involvement in the MPLSM task would do much to improve performance. Indeed, some members of the group feel that reducing error rates with the present machinery is primarily a personnel problem, not one of technology. Frequent error measurement and feedback could be used to develop a team spirit on MPLSM machines, and, if combined with a system of reward, may reasonably be expected to reduce errors with no effect on production (Herzberg et al. 1959). Appendix B describes possible measures of this sort suggested by a member of the group.

The Automatic Sorting of Mail

The working group was not requested to address the matter of automatically sorting letter mail by machine-readable codes entered on envelopes by customers sending mail. However, since human error in manually reading and key-sorting mail is so expensive and the potential for reducing error rates by manipulating human factors appears to be very small relative to accuracy realizable through automation, the group strongly encourages USPS efforts to develop automatic systems (see discussion in National Research Council 1972). The group is well aware of the difficulties to be faced: opposition from the public if a formatted code must be entered in a special area on an envelope; societal

problems caused by replacing operators with machines; and the expense of replacing one system with another. However, the character of sending mail is already changing with the advent of electronic systems to transmit some business mail from point to point (see, for example, Data Communications 1977; Hirsch 1978), and it is reasonable to expect that private mail should also undergo a change in procedure. None of the findings and recommendations in this report that might lead to improved performance of manual systems can, in the opinion of the working group, come close to the performance of an automatic system. The implementation of automation for handling mail, however, does not eliminate the requirement for considering the involvement of human factors. People will still be responsible for the design, programming, and supervision of any automatic system. It cannot be too strongly emphasized, therefore, that studies on human factors applicable to the design and operation of computer-controlled equipment should be conducted in support of the development and introduction of automated systems by the USPS.

RECOMMENDATIONS

During the course of its investigation, the working group examined a wide range of visual, auditory, and human factor considerations that might bear upon the performance of MPLSM operators; particular attention was given to operations at the keying console where sorting errors are made. The group identified four aspects of the operator's task in which alterations might produce fairly large improvements in error rate: pacing, error detection and correction, error-rate feedback, and motivation. Before instituting any change in any of these aspects of operation, the USPS would, of course, need to perform a thorough cost-benefit analysis. Such an analysis would include considerations in addition to the production of errors and is beyond the scope of this report.

The group recommends that the USPS study the feasibility and cost-effectiveness of four possible changes:

> Instituting task pacing by the operator rather than by the machine; if operator pacing cannot be accomplished, then shifting the start of the keyboard acceptance period forward in the cycle so that keying can begin while the letter is still stationary in the viewing window might lead to a minor improvement in the machine-paced task.
>
> Providing a self-detected error key (single character, clear all keys, or direct-to-re-sort bin) so that the operator may correct errors. Also, provide visual feedback of the code just keyed, in close proximity to the envelope for which it was just keyed, so that the MPLSM operator may visually check a suspected self-detected error before sending the envelope to a sort bin.

Providing operators feedback at frequent intervals on their own error rates.

Setting up a motivational system based on positive reinforcement (reward) of low error rates.

A system for measuring baseline error rate will be necessary in order to evaluate the effectiveness of these or any other changes in the MPLSM task. Thus, the working group strongly recommends the adoption of a system for collecting error data, such as the ones described in the section on findings and conclusions and in Appendix B.

The working group recommends that the USPS not institute a program to obtain on-line physiological data that may be correlated with stress and fatigue. Such a study would have to be conducted over a very long term to have any potential for showing results, and the difficulty and uncertainty of obtaining significant data argue against including this endeavor in the program plan of the USPS.

The working group considered a number of changes that might be made in the physical environment of the MPLSM operator and concluded that they would produce at best only small percentage improvements in operator error rates (in comparison with the large potential for improvement by the changes recommended above for study). Nevertheless, the volume of mail is so large[3] that a very small percentage improvement in the MPLSM operator error rate might conceivably produce important monetary savings. Thus, the USPS may want to consider making changes in some aspects of MPLSM operations even though the group concludes that their impact on operator percentage error rate will be small. Among these the working group considered changes in seating, keyboard and coding arrangements, work cycles, illumination and noise, and other environmental conditions.

<u>Seating</u>. A fully and easily adjustable chair with a footrest and lockable casters could contribute to operator satisfaction and might reduce fatigue (Cornog 1974, 1975; Lundervold 1958; Rohmert 1971; Tichauer 1973). A footrest is deemed important, but an armrest should be provided only to workers who want one and so should be removable.

<u>Keyboard and Coding Arrangement</u>. The present keyboard and coding layout is not of optimal design (Seibel 1972). Available evidence (Cornog 1976; Seibel 1972) or a new research and development program could doubtless suggest better ones. Improved keyboard design might reduce operator training time but is not likely to produce large improvements in performance by experienced operators.

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[3]Stated to be about 56 billion pieces of first-class mail sent yearly, with a cost of 7¢ per misdirected letter (correspondence from E. A. Danz, U.S. Postal Service, to D. A. Goslin, National Research Council, May 15, 1979).

Work Cycles. Minor changes in the time on the console relative to time on the sweep side of the machine will probably not change performance. Operators need adequate time to adapt to pacing and to processing a given number of letters; they also should not be at the console so long as to become fatigued. The present work-rest cycle appeared to be acceptable to those involved in the system (Cornog et al. 1969).

Illumination and Noise. Adequate lighting levels were observed by the working group in the two installations visited. Optimal lighting, if incorporated, would contribute little of substance to error reduction. Admittedly, the MPLSM work environment is noisy and any efforts to reduce noise levels are endorsed. However, there is no evidence that the current noise levels bear on performance, and dramatic reductions in noise cannot be predicted to reduce errors.

Other Environmental Conditions. Modern building design pays considerable attention to heating, cooling, and ventilation. While such matters may not be optimally provided in some of the older buildings occupied by the USPS, there is little likelihood that the environment is so out of the range of human comfort as to be a major determinant of mail-sorting errors. Thus, changing the environmental situation would be expected to have little effect (Rohmert 1971).

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APPENDIX A:
COMMENTS ON SOME PROCEDURES USED BY THE QUALITY CONTROL SYSTEM OF THE U.S. POSTAL SERVICE

Robert Seibel

A comparison of the Western Region's Quality Control Manual and the Southern Region's System Quality Sort Test strongly suggests that the Southern procedure is a small piece of the Western procedure. The Southern procedure is concerned with only the MPLSM bin test, while the Western procedure includes a MPLSM bin test as part of an overall quality control procedure.

The Western procedures, if followed dutifully and on a national scale, would go a very long way toward satisfying a demand for "good" statistics on error rates. All that is missing is a (nationally) standardized EDIT procedure and associated record keeping for keeping track of each individual operator (on an hourly, daily, weekly, monthly, or annual basis). The records on the individual operators would provide the sorely needed information feedback for self-monitoring and incentive, give the supervisors much needed information, etc.

A suggested variation on EDIT that might improve work involvement and incentive and be subjected to evaluation is:

1. Provide a separate EDIT bin for each keyboard station.

2. Computer controlled random selection of sample of letters (e.g., 10 every 25 minutes) from each keyboard station, with appropriate printout for each station.

3. Computer immediately signal operator at each station of number of "0" bin and "400" bin sorts, with some "very obvious" signals if the proportion gets above some value (e.g., 2 percent). Also immediately signal early keying, late keying, or any other "problem" that can be detected without examining the letter itself.

4. The correct keysort entries for each of the letters drawn via step 2 should be entered <u>in</u> <u>ink</u> on special data sheets. After the data sheets have been completed the entries should be checked against the computer printout. Data sheets and printouts should be filed

for later review by supervisory personnel.

5. Report the results of checking each operator's sample to the individual operator, and do so for each of their sessions at the keying station.

6. Enter results of steps 3 and 4 on a graph depicting each operator's performance for the session, the day, and the week.

7. The records of step 5 should be kept as part of each operator's performance file.

The need for more than just bin tests is pointed out in "Report to the Congress: Missent Mail--A contributing factor to mail delay and increased costs (B-114874)" by the Comptroller General of the United States, (U. S. General Accounting Office 1974): "Machine operators keyed 9.1 percent of the mail incorrectly. ... Even after screening, 3.6 percent of the mail sent between States was missent due to incorrect keying and machine error. ... An additional 3.1 percent of the mail sent between States was missent because correctly keyed mail was mishandled after sorting." The Western manual includes what they call Outgoing Pouch Tests (Section 5) and Machine Error Rate Test procedures (Section 4, modified via Directive of August 5, 1976). These procedures are crucial for establishing reasonable estimates of overall system error rates. The Western manual recommends the pouch test at least once per week.

There are two critical comments concerning the Western procedures: First, on page 5-9 (Section 5.5) for bundled mail in the pouch test--where, e.g., 5 pieces are to be selected from a bundle "...the first 5 letters of the bundle are taken as the sample pieces." This may introduce a strong bias in the estimate. Second, the timing suggestions for carrying out the various tests seem too fast for accuracy. For the pouch test (page 5-8, Section 5.44) the checker has just under 3.5 seconds per piece of mail (3 hours 55 minutes for 4,100 pieces); for the 277 bin test the checker has just under 2.2 seconds per piece (3 hours 45 minutes for 6,200 pieces); and for the 40 bin test the checker has 1.65 seconds per piece (1 hour 50 minutes for 4,000 pieces). That seems very fast. In the interest of speed, the manual (page 2-14(d)) requires that sampling and checking be done at the bin shelf--otherwise, it takes too much time. Yet, on page 1-25 (Section 1.H5 (d) & (e)) they recognize and comment on the possible interference with normal mail flow. It might be better to take a bit longer to make the checks in order to aid checking accuracy and to avoid interference with normal mail flow.

(The Southern manual contains what may be an error in their statistics on page 18 and Worksheet VIII: The -1.28 to +1.28 should be -1.96 to +1.96.)

APPENDIX B:
OPERATOR MOTIVATION AND TRAINING IN THE USE OF THE MULTIPLE POSITION LETTER SORTING MACHINE

Donald Erwin

These comments focus primarily on training and motivational aspects of the problem of reducing error rates on the letter sorting machine (LSM).

ACCURACY

The 98-percent accuracy goal for operators on the LSMs may be too high vis-a-vis current operating conditions.

In Ms. Gray's briefing, two operators who were able to achieve 1- and 2-percent error rates were described. Although these cases demonstrate that this level of performance is possible, it would seem to represent very high proficiency performance when one considers what the operator must do within 600 msec inspection time, as shown in Figure 1. Inasmuch as approximately 30 percent of letters do not have ZIP codes, the information processing demands on the operator are seriously increased a third of the time. For almost a third of all mail processed, the operator must search memory for a code corresponding to the region, building, state, etc. on the envelope and punch that code into the LSM. The literature on the processing of visual stimuli, accessing and retrieving memory codes, and response production indicates that the LSM operator's task is indeed demanding, particularly when the letter is without a ZIP code (see, for example, Haber and Hershensen 1973).

Working group members who used the LSMs in the training room at the Washington, D.C., post office can appreciate the difficulty of the LSM operator's task. Maintaining a 98 percent accuracy rate sorting single-digit practice cards at 60 per minute was quite difficult. Even after practice, an accuracy rate of 98-percent in this task would not be easy to maintain. LSM operators may view a 98-percent accuracy rate as thoroughly unattainable, so their motivation to achieve a level of performance even approximating a 2-percent error rate may be very low.

One can consider motivation in a work environment to be directly proportional to the worker's expectancy that his or her efforts will lead to a level of performance that is in turn associated with a level

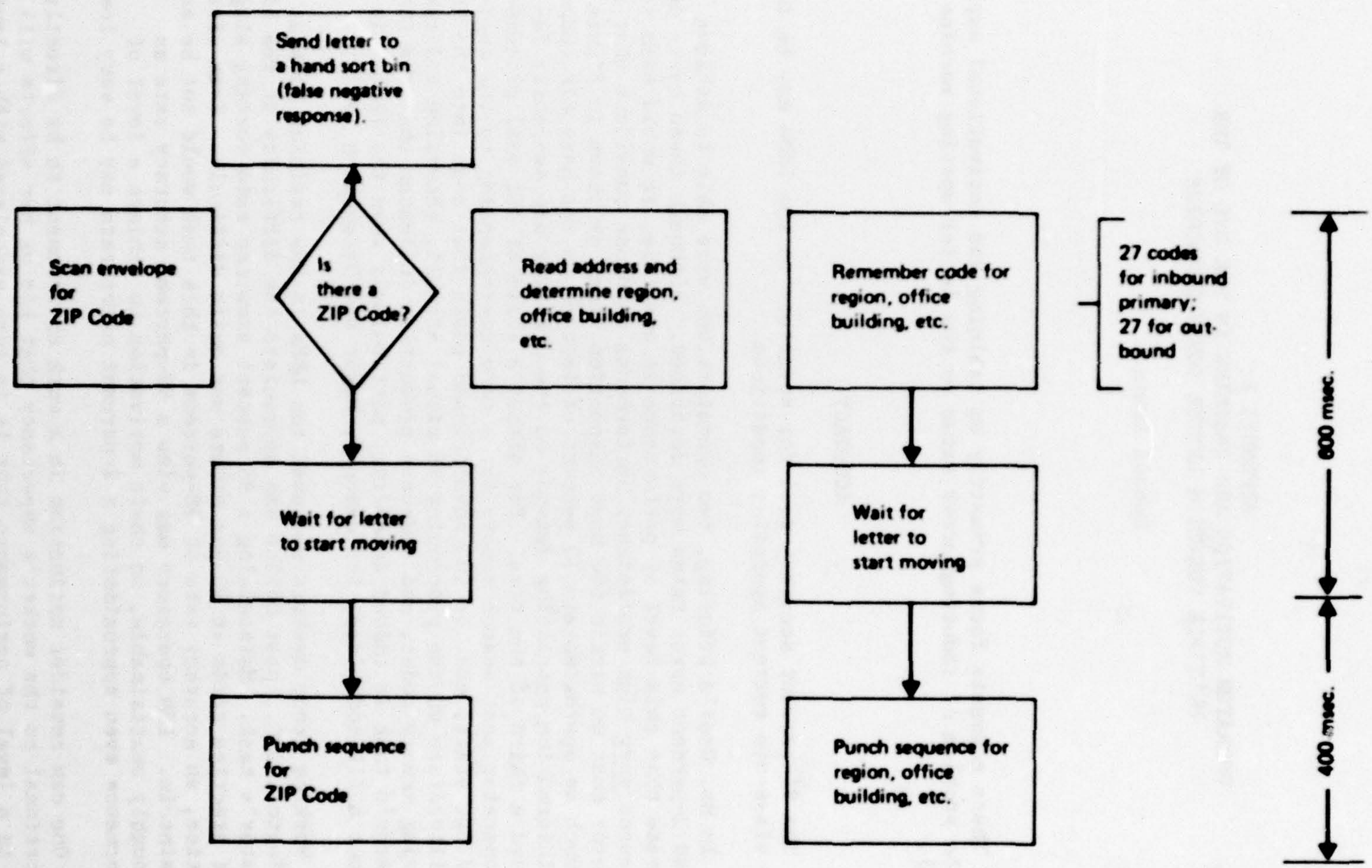

FIGURE 1 Information Processing and Performance Requirements of LSM Operators within One Second

of achievement that leads to desirable outcomes or objectives (Vroom 1964). When the LSM operator's motivational environment is considered in the context of Ms. Gray's briefing and the visit to the Washington post office, the following points emerge:

(1) LSM operators feel that no matter what level of effort is exerted, the probability that they can achieve a 2-percent error rate is very low; and,

(2) LSM operators may see little if any relationship between achieving very high accuracy rates and desired outcomes, such as promotions, salary increases, or recognition in the form of awards or commendations that are entered in personnel files.

(3) If LSM operators have minimal expectancies that their efforts can lead to low (i.e., 2-percent) error rates, and they do not perceive any significant relationship between good performance (i.e., error rates in the neighborhood of 2 percent) and the achievement of desired outcomes, their motivation on the job could be suffering.

LSM accuracy, as measured by supervisors and noted in personnel records, either may not accurately reflect actual error rates, or may not be a criterion for satisfactory job performance. Operators, knowing that achieving a 98-percent accuracy rate is very difficult and that it is not necessary to perform at that level to achieve desired outcomes, are motivated to only perform at a level at which the error rate will not be patently obvious to the supervisor.

Most LSM supervisors are former LSM operators. As such, they have developed certain expectancies about the achievability of 2-percent error rates. In the Washington post office, two supervisors said operators "rarely" go below 98-percent accuracy. The general impression conveyed was that the operation is running at about a 98-percent accuracy rate. Whether the Washington post office is really operating at a level significantly above the estimated error rate of 15-22 percent is indeterminable. Supervisors' statements that 98-percent accuracy is being maintained can be based on the fact that their audit procedures indicate 98-percent accuracy or on their general acquiescence to the conclusion that a 98-percent accuracy rate is unattainable. If it is assumed that supervisors are accurately reporting on the performance of their machines, then the audit procedure may be at fault for the conclusion that 98-percent accuracy rate is maintained.

If operators can anticipate audits and be sure that accuracy is high, then the supervisor has a very poor vehicle for evaluating performance, even if he or she wanted to enforce a 98-percent accuracy rate. But even if audit procedures could accurately reflect performance and supervisors wanted to enforce the 98-percent accuracy rate,

union contractual constraints appear to preclude the setting up of reinforcement contingencies that depend on level of performance. As this set of circumstances becomes obvious to the LSM operator, it becomes equally obvious that salary increases, promotion, etc. come just as quickly and regularly at 78 or 85-percent accuracy as at 98 percent. Consequently, operators do not perceive a 2-percent error rate as necessary for achievement of desired goals or objectives. Not only is there a minimal expectancy that high accuracy rates, such as 98 percent, are attainable, but also the perceived relationships between these high accuracy rates and desired outcomes such as promotion or a salary increase may well be nonexistent. The two dimensions of the LSM operators potential motivational structure are seriously lacking according to this analysis.

What can be done? First, it would seem necessary to increase operators' expectations that if they try they can achieve the level of performance requested by management. In other words, the accuracy rate has to be made realistic so operators can deal with it as part of reality. There are three ways this could be done: lower the accuracy rate until it is "realistic"; slow down the machines; or, encourage operators to make false negatives in the training program and on the job. (This point is discussed below; a false negative would be sending a letter to a re-sort bin if the operator is distracted, or slow, or unsure of the code.)

(A "realistic" accuracy rate or a reasonable machine rate for some level of accuracy will require experimentation with a randomly sampled N of LSM operators using actual equipment in an operational environment --ideally, on the job. But experimentation that manipulates "acceptable" accuracy rates or machine rates requires some technique of accurately and validly assessing performance. This difficult problem has yet to be solved and is mentioned several times in the body of the report.)

Second, it appears critical to associate attainment and maintenance of performance at specified accuracy levels with the potential achievement of certain desired outcomes or objectives. It is important to note here that the literature on job satisfaction indicates that the factors influencing satisfaction are not the inverse of those causing dissatisfaction (Herzberg 1968). Factors such as achievement, recognition, and responsibility play an important role in engendering job satisfaction; company policy, supervision, and work conditions are much more salient contributors to job dissatisfaction. In order to couple achievement of proficient performance with desired outcomes that will increase job satisfaction and motivation rather than merely avoid or minimize job dissatisfaction, it is necessary to first ensure that the input of job dissatisfaction factors are minimized in the work environment.

Consequently: LSM operators should be queried to determine their perceptions regarding the acceptability of administrative policy, supervision, work conditions, and salary for their job. It is also

necessary to design desirable outcomes or objectives that have to do with achievement, recognition, responsibility, and advancement.

Achievement and advancement, for example, could involve providing feedback on personnel selection factors for supervisors that have to do with LSM performance. This information should be provided in training and in performance updates at periodic intervals.

For recognition, a system of incentives and performance awards could be developed, such as "Station of the Week" or "This machine has operated at _____ accuracy for ____ days."

For responsibility, selected crews could be allowed to determine their own work schedules, strategies for maintaining accuracy, etc.

Third, LSM operators must come to perceive these outcomes as being contingent upon their achievement and maintenance of specified accuracy rates. In order to concretely associate these desirable outcomes with performance, supervisors have to be able to accurately evaluate operators' error rates. To do so, supervisors should be able to: audit anyone at any time and record satisfactory performance in an operator's personnel file; assign operators to retraining after appropriate warnings or audits; and utilize a more efficient and comprehensive audit procedure.

The basic thrust of this approach is to give the operator and the supervisor a realistic error rate that they know can be obtained and then couple the attainment of this performance rate with the potential for achieving desirable outcomes or objectives. These outcomes should be designed to increase job satisfaction and motivation only after those factors that cause job dissatisfaction have been minimized.

COLLECTIVE EFFORT

It is necessary to develop a collective effort on the part of the LSM station crew to maintain high accuracy levels. Errors can be caught on both sides of the sorting process. People removing mail from the bins are supposed to riffle through the letters that they pull and then place the bundle in another bin on a truck. This is the final check, so to speak, of the operator's accuracy. At the Washington post office, people were observed on one machine (at approximately five stations) performing this final check. These individuals did not know they were being observed. Each individual did indeed fan the bundle as it was removed, but at about the speed that one would use if searching for a green envelope in a bundle of white. The bins were filling and requiring handling by these operators at a speed of about one or two a minute. A supervisor was then asked to grab a bundle and riffle through for errors. He proceeded to do so at about a fifth the rate that had been observed in the operators.

Many errors could be caught on the other side of the LSM if there was a team or collective effort at each station to hold the error rate down. The individual emptying the bins has ample time to riffle slowly through the bundle of letters to identify errors. And if there was sufficient emphasis placed on accuracy, perhaps these operators would actively search the bundle for errors rather than fan the bundle while looking elsewhere.

How can a collective commitment to accuracy be engendered on the LSM? One possibility is to attempt to stabilize crews so that the same people are working together for some amount of time and a certain amount of group reliance can develop for the achievement of an accuracy award of some sort. This is as opposed to having the supervisor monitor the activity of the person pulling bundles from the bins and making sure that more time is spent per riffle. The most effective solution to this problem (i.e., getting the person behind the machine motivated to find errors in sorted bundles) may lie in a collective commitment to accuracy rather than through an extension of the supervisory function. Since there is no way to audit the accuracy of the bin puller, accuracy-conscious behaviors for these operators may be hardest to motivate. Two questions remain unresolved: What sort of contingencies can be set up for more accurate groups, and, is there any mechanism by which the bin pullers can be audited, such as sending a ZIP code through with letters in it that had to be recognized, and which would be inserted into the mail flow at a given rate by the supervisor. This sort of occasional target would tend to increase the vigilance of the bin puller.

EDUCATION AND TRAINING

In education and training, the gravity of making a false positive has to be highly stressed. Considering the expense of a false positive (when a LSM operator sends a letter to the wrong bin), it would seem preferable in the long run if operators made false negatives instead (sending a properly ZIP-coded letter to the no ZIP code or unclassifiable bin or even a bin designated as a "Panic Bin" for just that purpose). During and after training, the gravity of making a false positive should be repeatedly emphasized. Perhaps the exact magnitude of the problem can be explained to LSM operators and instructions given that if for some reason the operator is not able to make a classification or is distracted, or whatever, a particular code designated as a "Panic Button" should be hit but under no circumstances should the operator try to classify the ZIP code correctly and hit the proper code. The "Panic Button" should be very simple. It should also be emphasized that there is no "penalty" for false negatives (i.e., filling up the non-sort box does not go on one's performance record) but that false positives that are susceptible to audit do go on one's record.

This general theme should be incorporated into the training program. Rather than having the trainee move from one speed to another and

be allowed to make any number of errors at the new speed initially and then reduce the error rate and go to the next speed, errors at any speed should be discouraged. Initial runs at new higher speeds that have 10- or 20-percent error rates should require the trainee to return to the earlier rate and relearn at that particular rate. Only after a certain number of errorless runs or runs at a very low error rate would the trainee be allowed to advance again to the next speed. The training program has to emphasize the gravity of making a false positive and ingrain in the trainee the notion of "if in doubt, use the Panic Code."

In brief, false positives seem to be the problem. Steps must be taken to get trainees to make false negatives (sending letters to re-sort bins) if they are in doubt, or cannot remember a code, or are distracted. Emphasis on the gravity of making a false positive should begin in the training period and be reflected in the training procedures and should continue in the supervisors' handling of employees' performance records.

OPERATOR SELECTION

LSM operators should be made to feel they are a selected (not necessarily select) group. Do LSM operators really have a better chance at getting promoted or becoming supervisors? If so, do they know it? Do ordinary mail handlers apply for LSM jobs after they have x months of experience, and do only a certain percentage make it to actually operating an LSM machine? If so, do the operators know it? Can attention be paid to the working conditions of the LSM operators, or is this something that is discouraged by the union? The basic notion here is that perhaps the LSM crews can be made to feel that they are a selected group, and this could be accomplished by feeding back any information to the LSM operators that does indicate that they are a selected group or taking measures that cause the crews to get the impression they are. Perhaps more rigid personnel selection procedures that may in turn contribute to a different job description and more pay are the correct and union-acceptable way to go in this regard. In any event, I suspect that many constraints on this tack are imposed by the unions.

CONCLUSION

In addition to the above suggestions, I have some final thoughts. A motivation and morale questionnaire would be in order to get some estimation of LSM operators perceptions of (1) the extent to which they think that they can attain a 98-percent accuracy rate; (2) the extent to which maintenance of this accuracy rate influences their desired objectives; (3) the extent to which they see themselves as part of a team and a selected group of employees that are doing a skilled job; and, (4) the importance of factors leading to job satisfaction and

dissatisfaction in the LSM work environment. This sort of questionnaire would indicate the extent to which my above suggestions are on target.

Any work that is done is going to need some means of accurately assessing performance in realistic job settings. This problem has to be solved before any solution offered by the working group can be validated. I suspect that the greatest source of variance in this sort of problem is supplied by the unions. This area (coming up with an acceptable test for ideas that allows accurate and representative sampling of operator/crew behavior) should be a topic of central concern.

Although it may be beyond the scope of this report, cost-benefit considerations of any solutions will have to be considered. For example, suppose that the rate of the machines is reduced to 30 letters per minute, and the error rate drops to 1 percent. Does this slowdown in the volume of mail being handled require increased personnel and machines such that the eventual costs will exceed those incurred by a 15- to 22-percent error rate that is based on 60 letters per minute? Indeed, the possibility that some solutions will have implications that will eventually cost more than shipping falsely classified letters around the country will have to be considered.

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13. ABSTRACT

This report reviews and comments upon studies proposed by a U.S. Postal Service task force concerned with reducing operator error rates and improving job satisfaction with the Multiple Position Letter Sorting Machine (MPLSM). The major recommendation of the report is that the Postal Service study the feasibility and cost-benefit effectiveness of: (1) changing MPLSM operation from machine pacing to operator pacing; (2) providing an error key to enable operators to correct mistakes they themselves detect; (3) providing on-line feedback on personal performance to operator; and (4) rewarding operators who achieve low error rates. The importance of establishing an adequate system for measuring baseline error rates is emphasized.

The report also considers the structure of the work environment, including visual and auditory factors, and explores the possibility of complete automation of the sorting system.

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